AN ANALYSIS OF COLLECTIVE GOODS AND EXTERNAL EFFECTS UNDER CONDITIONS OF COMPLETE INFORMATION AND PARETO OPTIMALITY

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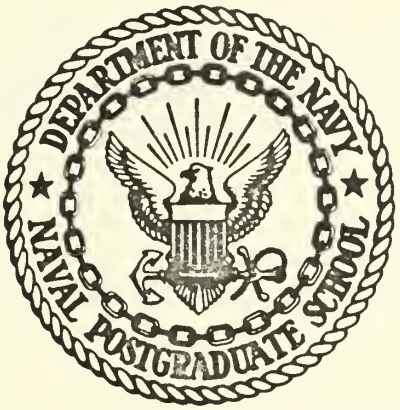

THESIS

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September 1970

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
September 1970

ABSTRACT

The allocation of resources is a problem which is faced by all decision makers whether they be public servants or private entrepreneurs. Increasingly these decisions have required more information than can generally be obtained through the decentralized pricing system of perfect competition. Many of the so called social problems of today, specifically environmental pollution, are deeply rooted in economic concepts which seem to cause allocations which are not Pareto optimal if determined by the market alone. This paper is confined to the study of two of the more important of these concepts, collective goods and external effects (or externalities).

The basic economic structure utilized is that of perfect competition under a criteria of Pareto optimality. After characterizing the Pareto optimal conditions for a world of private goods with complete information, separate models were described which included externalities and collective goods. It is shown that if a Pareto optimal solution is to be gained certain conditions exist which must be satisfied. The difficulty in attaining such equilibrium conditions is then discussed with a dynamic connotation for pedagogical purposes only. The general conclusions are drawn that when collective goods and external economies and diseconomies are present the market system or mechanism alone will not yield a theoretical Pareto optimal point.

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I. INTRODUCTION

"Environmental pollution, the unfavorable alteration of our surroundings, and its attendant problems govern the dynamics of the health and the economic and social well being of man." [Ref. 9].

Such statements have done much in recent years to focus attention upon environmental problems. That is, to increase the awareness of many persons, both in government and industry, to conditions which previously concerned only the conservationists. A number of governmental agencies have studied various aspects of the environment and their reports contain many technical details of the pollution problem.[1] Unfortunately, although the specific problems have been fairly well defined, proposed solutions to most of the more serious conditions are lacking. It is clear that as technology and population continue to grow, the pollution of the environment will continue to grow at a similar rate if unchecked. Therefore, it is imperative that plans be developed and implemented for environmental cleanup and waste disposal.

One should not imply from this, however, that nothing in the way of pollution control has been accomplished. There have been several isolated examples of concerted efforts to clean up a river or to eliminate sources of air pollution. Included among these are the very successful programs carried out by the City of Pittsburgh to purify its air and by the Ohio River Valley Water Sanitation Commission in eliminating a great portion of the Ohio River pollution. Even though these programs are considered successful, they have by no means been easy to

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[1] Butrico, Frank A., "Environmental Pollution in America," Current History, October 1968, p. 225. Footnote 2 lists some of the more important reports.

accomplish nor have they been all inclusive in their effect. The Pittsburgh plan "has been and continues to be a bitter, emotionally charged battle to keep the atmosphere pure enough to breathe and clean enough to see through". The Ohio River project was initiated in 1948, yet in 1966 there were still a number of industries located along the river that had failed to assume any responsibility for improving the water condition [Ref. 20].

The problem of environmental pollution control is a complex one spanning many disciplines. The purpose of this paper is to investigate the economic theory which can be related to the use of the environment and to examine in general the economic theory of public expenditure. Basically this study will examine the concepts of externalities and collective goods, pointing out their applicability to the pollution problem and the failure of the market system of decentralized pricing to cope with such wide ranging "public" problems. The terms "market failure" and "market inefficiency" are widely used throughout the literature to describe the inability of the pricing system to attain the true Pareto optimal point of a given market structure. They are, however, persuasive terms which could easily be interpreted in the literal sense that the market system is of no use at all. Actually the pricing system is employed in many situations to develop a solution which may not be Pareto optimal in the strict theoretical manner but is, say, the "second best" position. In this sense the market has not "failed" and to imply that it had would be wrong. Due to the almost universal usage throughout welfare economic literature, however, the term "market failure" will be used in a similar manner in this paper.

Although much of the economic literature has had a tendency to treat externalities as exceptional cases, it will be shown that at least in the area of environmental pollution (and other public problems) the concept of an external effect is central to the issue. The simple "ad hoc" arrangements which have been suggested to deal with the misallocation of resources due to externalities may no longer be adequate to contend with the immense present day problems. The simple analyses presented herein should serve to illustrate the fact that much more study in the area of "political economy" is necessary before economists may give more useful advice to the decision makers who are searching for solutions to these problems.

II. PURE PRIVATE GOODS WORLD

Perhaps a logical starting point would be a brief discussion of the basic principles of modern welfare economics. Welfare economics is really the normative aspect of economics as compared with the positive aspect. Whereas positive economics deals with the determination of results achieved under a given economic structure, normative economics is concerned with the relative merits of various economic systems. Positive economics is scientific in nature with its assumptions and conclusions subject to empirical testing to determine their validity. Welfare economics on the other hand is based upon assumptions which are largely value judgments and defy empirical or logical testing to establish their validity. If, however, we are given value judgments which define some state of the economy then the techniques of positive economics can be used to determine the feasibility of attaining that state under a certain economic structure. It is generally concluded that "the primary objective of welfare economics is to provide a guide for distinguishing between "desirable" and "undesirable" states of the economy" [Ref. 33]. Certainly the realization of the objective depends primarily upon the manner in which "desirable" state of the economy is defined. In effect the preferences of individuals form the fundamental basis for determining the desirability of a state of the economy. Since there is no obvious way to combine individual preferences, it becomes extremely difficult in many cases to choose the most desirable of several alternative economic states. (States of the economy may differ in many respects: competitive, monopolistic, and multimarket are some examples. A different allocation of resources normally characterizes each state.) [Ref. 22, 33].

Although welfare economics encompasses a broad spectrum of economic ideas, the central theorem of welfare economics deals with the equilibrium conditions of a competitive market.[2] Ayres and Kneese provide a very concise summary:

> "Modern welfare economics concludes that if (1) preference orderings of consumers and production functions of producers are independent and their shapes appropriately constrained, (2) consumers maximize utility subject to given income and price parameters, and (3) producers maximize profits subject to the price parameters; a set of prices exists such that no individual can be made better off without making some other individual worse off. For a given distribution of income this is an efficient state." [Ref. 1]

Appropriately constrained as used in the quotation above implies regularly smooth and quasi concave utility functions and production functions. These assumptions will continue to apply throughout this paper. In order to facilitate understanding of the ideas to be presented later concerning externalities, a general development of the Pareto optimal conditions for a purely competitive private goods world is necessary.

Private goods refer to those normally considered in economic literature. That is, they are unshared goods; consumption by one individual prevents consumption of that unit by another. Samuelson [Ref. 34] defines a private consumption good as those which can be parcelled out to different individuals such that the total available equals the sum of that received by each individual. Consider, then,

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[2] The major hypothesis of perfect competition as far as consumers are concerned is that the price of a commodity is not varied by the consumption level of an individual consumer. Also the prices of labor and privately owned resources are not affected by the sales of a single consumer. Perfect competition also dictates to firms that one alone cannot affect the price of a given commodity by varying its output of that commodity. Prices are varied in the market system but by aggregate supply and demand rather than individual.

a world of s individuals, k activities (producers) and m commodities. Assume that each firm uses each commodity either as an input or an output and that each commodity appears in the utility function of every consumer.

Let: X_h $(h = 1,2,\ldots,m)$ be the quantity of the h^{th} commodity.

x_{jh} $(h = 1,2,\ldots,m)$; $(j = 1,2,\ldots,k)$ be the quantity of the h^{th} commodity supplied by the j^{th} firm.

x^i_{jh} $(h = 1,2,\ldots,m)$; $(j = 1,2,\ldots,k)$; $(i = 1,2,\ldots,s)$ be the quantity of the h^{th} commodity supplied by the j^{th} firm and demanded by the i^{th} consumer.

The utility function of the i^{th} consumer is

$$(1) \qquad U^i = U^i\ (x^i_{j1},\ x^i_{j2},\ \ldots,\ x^i_{jm});\ (j = 1,2,\ldots,k)$$

$\sum_{j=1}^{k} x^i_{jh}$ is the quantity of X_h consumer i consumes. The "goods" consumed also include the factors such as labor which the consumer provides as inputs to producers. In effect an individual is trying to maximize his consumption of outputs and at the same time minimize his total of inputs supplied. Thus by using proper signs both outputs and inputs can be included in the utility function.

Each firm is faced with a production function which has the implicit form

$$(2) \qquad F^j\ (x^i_{j1},\ x^i_{j2},\ \ldots,\ x^i_{jm}) = 0;\ (i = 1,2,\ldots,s)$$

As with the utility function the x^i_{jh}'s can represent either outputs or factors of production depending upon their sign.

The goal of this hypothetical world is to simultaneously maximize all consumer's utility subject to the constraints imposed by the production functions. Recall from traditional textbook definitions the meaning of Pareto optimality; among consumers a distribution of goods

is Pareto optimal if every reallocation of goods results in a reduction of utility for at least one consumer. Similarly production is Pareto optimal if every reallocation of inputs among firms causes the output level of at least one firm to decrease. The positive economic analysis of perfect competition has demonstrated that at equilibrium the necessary conditions for Pareto optimality are satisfied. Such analysis does not, however, give a unique point at which welfare is maximized. Instead we find an infinite number of points which satisfy the Pareto optimal conditions; that is, an efficiency or Pareto optimal frontier. Each point has the Pareto optimal characteristic that movement away from it must always hurt one person while helping another. In order to determine the "ideal" state of this world or to judge the relative desirability of all the alternative points the society must make further value judgments [Ref. 22, 33].

The impossibility of Pareto optimality alone to determine the "bliss" point of society has led to development of the social welfare function concept. A social welfare function is a rule for ranking states of the economy in terms of social desirability and uses as its basic data source the individual preferences of all members of the community. Samuelson refers to the social welfare function as a set of norms which renders interpersonal judgments and which has the special property that at each point a move by each man to higher indifference curve results in increased social welfare.[3] The general form of the social welfare function is

[3]Samuelson, Paul A., "Diagrammatic Exposition of a Theory of Public Expendature," The Review of Economics and Statistics, Nov 1955, p. 351-352. A great deal has been written in recent years concerning the social welfare function. It is not the purpose of this paper to examine the premises and assumptions upon which the concept is based, but rather to employ the concept in the analysis at hand. Interested readers may pursue the topic more fully especially in Human Values and Economic Policy, edited by Sidney Hook (New York University Press, New York, 1967).

$$(3) \qquad W = W\,(U^1, U^2, \ldots, U^s)$$

where U^i is the utility function of the i^{th} consumer. Additionally the social welfare function satisfies

$$(3a) \qquad \frac{\partial W}{\partial U^i} > 0 \text{ for all } i.$$

Thus determination of the welfare optimum becomes a problem of maximizing the social welfare function subject to the production function or

$$(4) \quad \text{Maximize} \quad W[U^i(x^i_{jh})]; \; (i = 1,2,\ldots,s)$$

$$(5) \quad \text{Subject to} \quad F^j\,(x^i_{j1}, x^i_{j2}, \ldots, x^i_{jm}) \leq 0$$

$$(6) \quad \text{and} \qquad x^i_{jh} \geq 0$$

Forming the Lagrangian

$$(7) \quad L = W(U^1, U^2, \ldots, U^s) - \sum_{j=1}^{k} \lambda_j F^j\,(x^i_{j1}, x^i_{j2}, \ldots, x^i_{jm})$$

At optimality the following conditions must be satisfied

$$(8) \quad W_i \frac{\partial U^i}{\partial x^i_{jh}} - \lambda_j \frac{\partial F^j}{\partial x^i_{jh}} \leq 0$$

$$(9) \quad x^i_{jh}\left[W_i \frac{\partial U^i}{\partial x^i_{jh}} - \lambda_j \frac{\partial F^j}{\partial x^i_{jh}}\right] = 0$$

where $W_i = \dfrac{\partial W}{\partial U^i}$ and

$$(9a) \qquad F^j\,(x^i_{j1}, x^i_{j2}, \ldots, x^i_{jm}) \leq 0$$

$$(9b) \qquad \lambda_j\,[F^j\,(x^i_{j1}, \ldots)] = 0$$

From (9) it can be seen that if the optimal quantity of x^i_{jh} is positive then equation (8) holds with strict equality. Also since $\lambda_j \geq 0$ then

(9a) holds with strict equality when λ_j is positive. Now comparing any two quantities, h and h', observe that

$$(10) \qquad \frac{\dfrac{\partial U^i}{\partial x^i_{jh}}}{\dfrac{\partial U^i}{\partial x^i_{jh'}}} = \frac{\dfrac{\partial F^j}{\partial x^i_{jh}}}{\dfrac{\partial F^j}{\partial x^i_{jh'}}}$$

The left hand side of (10) is called the rate of commodity substitution (RCS) for consumer i between goods h and h'. The right hand side is known as the rate of product transformation (RPT) for firm j between goods h and h'.

Harking back to the descriptive analysis of perfect competition, recall the important results at equilibrium whereby the RCS between any two goods were equal for all consumers. Analogously the RPT between any two goods were equal for all firms. Also recall that in perfect competition the prices faced by all consumers and producers for a given good are the same. One additional result of this analysis is necessary for our purposes here and that is the fact that the rates of commodity substitution and product transformation are, at equilibrium, equal to the price ratio of the commodities involved.

Now how do these results apply to the situation in which a social welfare function is included in the analysis? First notice from equations (8), (9) and (9a) that there are the same number of equations as unknowns. (The unknowns are the x^i_{jh}'s which are positive and the λ_j's which are positive.) Thus the welfare optimum can be completely characterized and, in theory at least, optimal values of all commodities can be determined. The structure of the problem ensures that the equilibrium allocation will be Pareto optimal. Equation (10) verifies

that the rates of commodity substitution are the same for all consumers and also equal to the rates of product transformation for all firms.

The foregoing analysis falls into the category of equilibrium analyses. Nothing is said nor implied as to whether the equilibrium point as described can actually be attained. Since equilibrium in its most restrictive sense implies a state of affairs in which things are at rest, the study of such a condition would not give a great deal of insight to the questions at hand. What really is more important and more interesting are the laws of change that an equilibrium suggests. The tendencies to move toward or away from the equilibrium point are actually more significant in many cases than the characteristics of the point itself. When one begins to discuss methods by which such an optimal allocation can be achieved one enters the realm of disequilibrium analysis which deals with a process as compared to the static condition of equilibrium. Thus this discussion will include sections of dynamics as well as equilibrium analysis. Special mention will not again be made when a shift of emphasis occurs.

Most economists concur in the conclusion that for perfect competition the Pareto optimal allocation can be achieved through a market type system in which prices of commodities become the motive force pushing toward equilibrium. This is referred to as a decentralized system because each individual and firm can decide for himself whether his situation is optimal and if not can take individual and separate action to make it so. There is no centralized authority necessary to specify what is produced, how much is produced and who gets it. There is, however, the "invisible hand" which guides all consumers and firms through the pricing system to equilibrium.

A vital consideration which enters into such a system is that of ownership. That is, the goods and services which form the economic system must be able to have a price assigned to them. For the most part this requires two things. First the goods and services must be owned; property rights must be in effect. Secondly and maybe more important, some method of excluding the benefits of the good or service from those who do not pay for them must be available. Musgrave [Ref. 28] flatly states that the exclusion principle must apply if a market mechanism is to function properly.

There are a number of situations where the market mechanism as described by the foregoing disequilibrium discussion seems to require modification for the efficient allocation of resources. If left to the price forces of the market alone a non-optimal position will be attained and the social welfare function will not be optimized. It is not within the scope of this paper to investigate all of these aspects of the market mechanism but rather to focus attention upon two specific areas of market modification; externalities and collective goods.

III. EXTERNALITIES

It has been said that externality dominates theoretical welfare economics [Ref. 7]. The literature, however, agrees only in that the concept of external effects is difficult to define and almost impossible to analyze. In many instances writers have grouped several distinct types of market inefficiencies under the common heading of externality when some, such as that caused by risk and uncertainty, have very little, if any, connection with the more common thoughts concerning external effects. Before conducting an equilibrium analysis of the market in which external economies and diseconomies become important, it is first necessary to gain an understanding of the concept.

Viner first made a critical distinction between what are called pecuniary external economies and technological external economies but they both dealt only with firms and their long run supply curves. Pecuniary external economies will cause the long run supply curve of an industry to decrease because an input price decreases and the demand for it increases. Technological external economies consist of other improvements in efficiency which are not reflected in input prices.[4] Although not used in Viner's strictest sense, the term technological externality has come to encompass most of what we now consider to be market external effects.

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[4] Bator, Francis M., "The Anatomy of Market Failure," Quarterly Journal of Economics, Aug 1958. Pecuniary externalities or economies of scale are not to be considered further herein. They are mentioned because (a) the term does arise several times throughout the literature with inadequate explanation and (b) the original Marshal-Pigou proposition concerning externalities were really talking of pecuniary externalities although their tax-subsidy conclusions actually remain applicable to what we now call technological externalities.

Buchanan and Stubblebine [Ref. 7] have proposed perhaps the most general definition of externality and one which has probably gained the most far reaching acceptance. According to their definition, an externality is present when the utility of an individual is dependent not only upon activities under their own control, but also upon other activities under control of another individual. An activity as used in this context means "any distinguishable human action that may be measured". Although they speak only in terms of consumers, the same definition applies to the producing sector if "utility of an individual" is replaced by "output of a firm". An external economy exists when increasing an activity causes an increase in utility (or output for a firm). Conversely an external diseconomy implies disutility or decreased output from an activity increase.

The effects just described have also been referred to as the general doctrine of direct interdependence or direct interaction. In reference to the perfect competition market system "direct" infers that the interdependence does not operate through the market mechanism. These interactions can be broken down into several distinct types, each of which has been studied separately many times. They are: (a) consumer-consumer, (b) consumer-producer, (c) producer-consumer, (d) producer-producer, and (e) collective interaction. Each will be discussed in turn in the paragraphs to follow.

First consider consumer-consumer interaction whereby an individual's utility is not only dependent upon the goods and services which he consumes or renders but also upon the consumption of others. For instance an individual may derive satisfaction from the fact that another individual has a high level of consumption (possibly ones own

children).[5] Another consumer-consumer relationship which is extremely important (especially in the light of opening statements of this paper) concerns the "spill over" effect of one individual's consumption upon another. Essentially these are the residuals of consumption which are not completely assimilated by the environment over which an individual holds specific property rights. Consumption in this context includes full utilization of the service provided by the good and is not meant to imply a separate production activity by consumers. Examples are automobile exhaust, trash and garbage; we all pollute each other [Ref. 12].

Consumer-producer interaction occurs when a consumer effects a producer's output in ways other than services offered and demand for products. Although examples of this are difficult to enumerate, Skitovsky [Ref. 37] offers the instance where inventions which facilitate production become available to producers free of charge.

The third category of interaction, producer-consumer, is an extremely common one which has concerned many writers for years. The interaction arises from the fact that consumers utility not only depends upon the goods and services produced by the firm and obtained through the market mechanism, but also upon "residuals of production" which normally are a disutility to the individuals involved. Such conditions have resulted in much of what is now considered environmental pollution; smoke, slag, waste discharged to rivers and streams and so forth.

[5] These are sometimes referred to as "psychic" external effects. Such externalities are difficult, if not impossible, to measure and thus are not considered in Buchanan's development. One can think of many examples, however, whereby a person's utility (or happiness) has been lessened through envy of another's consumption. Skitovsky [Ref. 37] has indicated that this interdependence is the major cause of the "reluctance of economists to make any welfare statements concerning the consumer".

Direct interaction between producers occurs when the output of a firm depends upon the activities of other firms in addition to the actual factors required for production. As an example consider a firm which must filter and purify its air prior to entry into its factory because of smoke particles emitted by a neighboring factory. The clean air factory has no direct control over the amount of smoke particles in the air and thus is required to provide purification which would be unnecessary if the neighboring firm were absent. Much of the classical work in external effects has been concerned with this type externality and it was in this context that Pigou's tax-subsidy proposals were first advanced.

Collective interaction can be characterized by social services provided, equally and free of charge to all persons, by the community through its government. The importance of external effects which are generated in this manner has been shown in Samuelson's analysis of collective consumption (public) goods [Ref. 34, 35, 36]. Public goods will be discussed more in detail later but suffice it to say for now that Samuelson's public goods exhibit external effects to an extreme degree [Ref. 37, 2].

Now that a fairly detailed description of the actions which comprise an external economy or diseconomy has been set forth, the development of this investigation could proceed in either of two directions. First, an attempt could be made to delineate the various causes for interaction which would appear to be extremely important if solutions to the market failure problem are to be proposed.[6] Secondly (and the

[6] "Causes for interaction" refer to such concepts as nonappropriability of resources, ownership (or lack of ownership) problems and exclusion difficulties and cost. Bator [Ref. 2] discusses these aspects at length. Musgrave [Ref. 28] and Meade [Ref. 24a] also provide insight to these problems.

path which will be followed) is to discuss mathematically the effect external economies and diseconomies have on the perfect competition equilibrium model previously outlined. It must be remembered that this is an institution free equilibrium analysis. Transfer costs, information costs, government regulation and other typical institutional mechanisms are to be ignored.

To begin such an analysis let us first redefine the utility and production functions. Assume for complete generality that each individual's utility is a function of not only his own consumption but also the consumption of every other individual in the community. Similarly each firm's production function depends upon the outputs and inputs for every other firm. Therefore the utility function is of the form

$$(11)\quad U^i = U^i(x^1_{j1}, x^1_{j2},\ldots, x^1_{jm}, x^2_{j1}, x^2_{j2},\ldots, x^2_{jm},\ldots, x^s_{j1}, x^s_{j2},\ldots, x^s_{jm})$$

$$j\ (j = 1,2,\ldots,k).$$

and implicit production functions are

$$(12)\quad F^j\ (x^i_{11}, x^i_{12},\ldots, x^i_{1m}, x^i_{21}, x^i_{22},\ldots, x^i_{2m},\ldots, x^i_{k1}, x^i_{k2},\ldots, x^i_{km}) \leq 0$$

$$i\ (i = 1,2,\ldots,s)$$

Forming a Lagrangian function similar to (7)

$$(13)\qquad L = W(I^1, U^2,\ldots, U^s) - \sum_{j=1}^{k} \lambda_j F^j$$

Now once again examine the conditions which are necessary if an optimal solution exists.

$$W_1 \frac{\partial U^1}{\partial x^1_{jh}} + \sum_{i=2}^{s} W_i \frac{\partial U^i}{\partial x^1_{jh}} \leq \sum_{j=1}^{k} \lambda_j \frac{\partial F^j}{\partial x^1_{jh}}$$

$$W_2 \frac{\partial U^2}{\partial x^2_{jh}} + \sum_{\substack{i=1 \\ i\neq 2}}^{s} W_i \frac{\partial U^i}{\partial x^2_{jh}} \leq \sum_{j=1}^{k} \lambda_j \frac{\partial F^j}{\partial x^2_{jh}}$$

(14)

$$\vdots$$

$$W_s \frac{\partial U^s}{\partial x^s_{jh}} + \sum_{i=1}^{s-1} W_i \frac{\partial U^i}{\partial x^s_{jh}} \leq \sum_{j=1}^{k} \lambda_j \frac{\partial F^j}{\partial x^s_{jh}}$$

$$x^1_{jh} \left(\frac{\partial L}{\partial x^1_{jh}} \right) = 0$$

$$x^2_{jh} \left(\frac{\partial L}{\partial x^2_{jh}} \right) = 0$$

(14a)

$$\vdots$$

$$x^s_{jh} \left(\frac{\partial L}{\partial x^s_{jh}} \right) = 0$$

(15) $$F^j(*) \leq 0$$

(15a) $$\lambda_j \left(\frac{\partial L}{\partial \lambda_j} \right) = 0$$

Again if the optimal quantity of a commodity is positive the equations of (14) must hold with strict equality. The system of equations can be solved although very often the computational difficulties may be extreme. The structure of the problem again assures that the solution will be Pareto optimal.

The completely general case described above, in which all types of consumer and producer interactions are involved, becomes very difficult

to analyze and isolation of the effects is nearly impossible. Additionally situations in the real world which must account for all external effects simultaneously are extremely rare. For these reasons certain assumptions will be made in order to facilitate the discussion and to allow more meaningful conclusions to be drawn.

First consider only externalities between consumers and those concerning producer initiated external effects which cause consumer's utility to be altered. Then (14) becomes

$$W_1 \frac{\partial U^1}{\partial x^1_{jh}} + \sum_{i=2}^{s} W_i \frac{\partial U^i}{\partial x^1_{jh}} = \lambda_j \frac{\partial F^j}{\partial x^1_{jh}}$$

$$\vdots$$

(16)

$$W_s \frac{\partial U^s}{\partial x^s_{jh}} + \sum_{i=1}^{s-1} W_i \frac{\partial U^i}{\partial x^s_{jh}} = \lambda_j \frac{\partial F^j}{\partial x^s_{jh}}$$

The term $\sum_{i=2}^{s} W_i \frac{\partial U^i}{\partial x^1_{jh}}$ represents the effect upon all other consumers of the consumption by individual one of the quantity x_{jh} of the h^{th} commodity produced by the j^{th} firm. In attempting to equate RCS with RPT it becomes clear that strict equality is not possible. In addition to considering an individual's RCS between two goods the combined effect of the consumption upon all other consumers must also be included. Economists normally refer to this condition as a divergence between benefit and cost. That is, if, through the market system, prices are used to determine the amount of good to be produced (and consumed) there will be an inequity when compared to the "optimal" amount of the good required to satisfy the entire society.

To see why this occurs first examine the effect upon other individuals in the community. It has already been assumed that $W_i > 0$ for all individuals. Thus the term $\sum_{i=2}^{s} W_i \frac{\partial U^i}{\partial x^1_{jh}}$ could be positive, negative or zero depending upon each consumer's change in utility with an increase of person one's consumption. There is no requirement that each individual be effected in the same "amount" or even in the same manner; some could experience an increase in utility while others suffered a decrease. What becomes more important than individual effects, however, is the cumulative effect which the summation above represents. If this is positive, which in this pedagogically dynamic discussion represents an overall social utility greater than that gained by person one alone, then the pure competition model will cause only that amount to be produced which satisfies person one. Thus society experiences an underproduction of the good. Conversely, should a cumulative diseconomy result from person one's consumption of good x_{jh}, the pricing system of determining the optimal output will cause more to be produced than is actually optimal for the community. If there were some manner to compute the cumulative "social utils" of the community and if a mechanism existed whereby this could be equated to the cost of production, then a Pareto optimal output would be determined. The fact that these mechanisms do not exist has given rise to the common economic view that when external economies and diseconomies are present the market system causes a divergence between private and social costs and benefits. When such a divergence occurs then the Pareto optimal conditions cannot be satisfied. This situation has touched off much study and debate as attempts have been made to reconcile the difference. Some of the efforts in this area will be discussed later

but for now it can be declared that the solutions are neither obvious nor simple.

IV. COLLECTIVE GOODS

Next consider the interdependencies which arise due to a special category of goods known in the literature as collective or public goods. Before proceeding to an equilibrium analysis of an economic structure which includes both private and collective goods, it is first necessary to discuss the concept in general terms. Samuelson [Ref. 34] first defined a "collective consumption good" as one

> "which all enjoy in common in the sense that each individual's consumption of such a good leads to no subtraction from any other individual's consumption of that good".

Such a good differs from a private good (or individual consumption good) in one most significant way. A private good has the characteristic that if one person consumes a unit of it nobody else can consume that unit. My loaf of bread can be consumed by no one else. The total amount of bread produced is equal to the sum of bread consumed by each consumer. A collective good on the other hand is characterized by the fact that the total amount produced must be consumed by each and every individual. A person cannot decide unilaterally how much of a pure collective good he will consume. In a later article Samuelson referred to such a good as a "public consumption good" [Ref. 35]. Since then the term "public good" has taken on several different connotations and thus no longer can be used synonomously with "collective good" which appears to have retained its original definition.[7] Therefore when

[7] For example Musgrave [Ref. 28] refers to a public good as one, "the inherent quality of which requires public production". It will be shown that collectiveness does not imply public production. Buchanan [Ref. 4] on the other hand calls any good or service which is demanded and supplied through political institutions a public good. Duncan Foley [Ref. 19] adds yet another distinction by defining a public good as one which requires involuntary total consumption by all individuals. These examples are not exhaustive but serve to illustrate the difficulty in attempting to reconcile the various uses of "public good" to some common denominator.

referring to a good which exhibits the equal consumption property it shall be called a "collective good".

Typical examples of collective goods include national defense for a nation, flood control for a geographical area, fire or police protection for a city or pleasant looking gardens and trees for a neighborhood. Notice each of the examples includes a locational notion. This becomes important when trying to define the group involved in a certain economic structure. Examples such as these have been used throughout the literature to illustrate the collective concept even though most require locational or definitional qualifications. Only recently have the problems associated with the environment been categorized as collective but if closely examined it can be seen that the concept is very intimately tied into the pollution woes. Many cases of pollution involve some "good" (such as smoke which blocks out the sun) the total effect of which is equally consumed by all members of the group. Additionally any scheme whereby a pollutant is removed or cleaned up again will effect all individuals equally.

Much of the early criticism of Samuelson's theory was a direct result of his stringent definition of a collective good. Almost any example of a collective good could be shown to be restricted in the equal consumption requirement. For instance many common public services such as highways, courts of law and police protection are subject to capacity limitations which are usually met long before the good has been made equally available to all [Ref. 24]. Most writing in the field of collective goods has now come to the understanding that most services and goods which exhibit the collective characteristics need not do so in the extreme manner of Samuelson's definition. It is recognized

that there are optional collective goods whereby persons can choose the amount he wishes to consume. A specific example might be television (via the radio spectrum, not cable) which possesses the collective characteristic but which need not be consumed in total by every individual. There can also be semi-optional goods such as street lighting. A person can choose whether he wants to live in a lighted area or not. If he opts for lighting then he must consume it. Yet he need not consume the same amount as everybody else because his relative location with respect to the lights determines the amount he consumes. And then finally there are non-optional goods which must be consumed by all but not necessarily in equal amounts. It will be shown subsequently that all of the above mentioned types of collective goods give essentially analogous conclusions in the equilibrium analysis.

In an attempt to relate collective goods to other economic concepts we shall now investigate the joint supply characteristic. Clearly once the good is produced a unit of it may be made equally available to all and thus it is "jointly supplied". In reality, however, many times a service will suffer a loss of quality as the number of consumers increases. An example might be an airport which offers a collective service the quality of which varies with the number of people it services. As traffic through the airport increases, the services provided each customer decreases. Theoretically each consumer receives equal service but the amount is less. Samuelson took note of the controversy and in his second article he admitted that his collective good should be regarded only as an "extreme polar case", the other pole being the "logically - extreme category of a private good". He went on to make the point however that even though a good or service did

not fit his extreme definition it could not be assumed that this automatically placed it in the private good category. Most examples of the economic functions of government are actually "a blending of the extreme antipodal models" [Ref. 35]. It has even been shown that some purely private individual consumption goods and services possess characteristics of a pure collective consumption good [Ref. 41]. As a result, Head, in his review of Samuelson's theory, stated that

> "Jointness thus remains an essential characteristic of a public (collective) good in the less extreme sense that a given unit of the good, once produced, can be made at least partially available, though possibly in varying degrees, to more than one individual. Only beyond a point does additional consumption by one person imply the need for a corresponding reduction in consumption by others." [Ref. 21].

Since the concept of "partially available" is difficult to interpret in an analytical sense, we will continue to represent a collective good as one which embodies the equal consumption characteristic. Upon completion of the analysis to follow it will be shown that relaxation of the equal consumption requirement does not affect basic conclusions concerning optimality.

Next it is important to observe that the concepts of collective goods and externalities are closely related. First, in simple terms, consider a collective service such as cleaning up a beach. Suppose only one half of the people who normally use the beach join in the clean up action. Clearly their utility will be increased when the clean up is completed but in addition the other half who also use the beach will experience a similar increase in utility. That is, their utility becomes a function of the services "purchased" by others and therefore a clear situation involving an external economy exists. This might even be considered to be a producer-to-two-types-of-consumer externality.

The issue here again revolves about the exclusion principle or actually the "impossibility of exclusion". It becomes extremely costly for a firm or individual to exclude non-payers from the benefits (if not full at least partial benefit) arising from the production or consumption of a collective good. Musgrave relates collective goods and impossibility of exclusion through his definition of "social wants" which he calls "those wants satisfied by services which must be consumed in equal amounts by all. People who do not pay for the serivces cannot be excluded from the benefits that result..." [Ref. 28]. Therefore the Samuelson collective good exhibits external economies (or diseconomies) to an extreme degree and properly belongs in any discussion of market inefficiency due to externalities.[8]

Consider now an analytical description of a perfect competition economy of private and pure collective goods. Harking back to the pure private goods world, recall that there were s individuals, k firms and m commodities. Now instead of all m commodities being private goods let $(x_1, x_2, \ldots, x_n)$ be private goods and $(x_{n+1}, x_{n+2}, \ldots, x_m)$ be pure collective goods. Thus each of the s individuals must consume an amount of each collective good equal to the total produced. That is

$$(17) \qquad x^1_{n+1} = x^2_{n+1} = \ldots = x^s_{n+1} = \sum_{j=1}^{k} x_{j(n+1)} = x_{n+1}$$

where $x_{j(n+1)}$ is the amount of the $(n+1)^{st}$ good produced by the j^{th} firm.

[8] Much of the preceding was based upon thoughts presented by J. G. Head [Ref. 21]. For a somewhat different examination of the role of the exclusion principle in theory of externalities, see R. Millward, "Exclusion Costs, External Economies, and Market Failure," Oxford Economic Papers, March 1970. In this article Millward examines exclusion costs, as separate from production costs, and the necessity of exclusion facilities in a market system. The inapplicability of the exclusion principle to collective goods is, in his opinion, due to the infinite cost of exclusion facilities for these goods.

Assume further that there are no private good external effects; an individual's utility is a function only of the goods (private or collective) which each actually consumes. Similarly each firm's production function depends only upon its own output. From the consumer's utility viewpoint there is no difference between the private and collective goods. He still prefers one bundle of goods to another and these bundles include both private and collective goods. Thus each consumer's utility function can be represented by

$$(18)\quad U^i = U^i\,(x^i_{j1},\ x^i_{j2},\ \ldots,\ x^i_{jn},\ x_{j(n+1)},\ x_{j(n+2)},\ \ldots,\ x_{jm});$$

$$(j = 1,2,\ldots,k)$$

and the production function for the j^{th} firm becomes

$$(19)\quad F^j\,(x^i_{j1},\ x^i_{j2},\ \ldots,\ x^i_{jn},\ x_{j(n+1)},\ x_{j(n+2)},\ \ldots,\ x_{jm}) \leqq 0$$

$$(i = 1,2,\ldots,s)$$

The x^i_{jh}'s carry the same interpretation as when previously used in the strictly private goods world. The social welfare function (see equation (3)) will again be utilized in the maximization of utility with the resulting Lagrangian:

$$(20)\qquad L = W\,(U^1,\ U^2,\ \ldots,\ U^s) - \sum_{j=1}^{k} \lambda_j\, F^j$$

Once more the necessary conditions for an optimum solution must be examined

$$(21)\qquad \frac{\partial L}{\partial x^i_{jh}} = W_i \frac{\partial U^i}{\partial x^i_{jh}} - \lambda_j \frac{\partial F^j}{\partial x^i_{jh}} \leq 0$$

for private goods (h = 1,2,...,n).

$$(22)\qquad \frac{\partial L}{\partial x_{jr}} = W_1 \frac{\partial U^1}{\partial x_{jr}} + W_2 \frac{\partial U^2}{\partial x_{jr}} + \ldots + W_s \frac{\partial U^s}{\partial x_{jr}} - \lambda_j \frac{\partial F^j}{\partial x_{jr}} \leq 0$$

for collective goods (r = n+1, n+2, ..., m)

$$x^i_{jh}\left(\frac{\partial L}{\partial x^i_{jh}}\right) = 0 \tag{23}$$

$$x_{jr}\left(\frac{\partial L}{\partial x_{jr}}\right) = 0 \tag{23a}$$

$$\frac{\partial L}{\partial \lambda_j} = F^j\,(x^i_{j1}, \ldots, x_{jm}) \leq 0 \tag{23b}$$

$$\lambda_j\left(\frac{\partial L}{\partial \lambda_j}\right) = 0 \tag{23c}$$

Equations (23) and (23a) indicate that if x^i_{jh} and x_{jr} are positive (that is, produced) in the optimal allocation then equations (21) and (22) hold with strict equality. Once more the set of equations are solvable even though the computational techniques might be complex. The interesting question again concerns the attainability of these conditions by the market mechanism.

Referring back to the analysis of the pure private goods world the identity of equation (21) with equation (8) implies that equation (10) is applicable to the private goods in this mixed goods world. Thus by analogy, at least where private goods alone are concerned, the optimal solution can be attained through the price mechanism. This really is of little importance when considered alone, however, because a person does not conciously separate out the private and collective goods in his utility function.

Now consider a collective good (n+1) and the same private good h', as previously considered.[9] The marginal rate of product transformation

[9] Private good h' could be considered a numeraire and then the marginal rates of substitution referred to in the text could actually be considered marginal valuations. Mishan [Ref. 26] used this approach to examine various situations involving private and collective goods with and without externalities.

between the collective and private good is no longer equal to the rate of commodity substitution for each consumer but rather is equal to the sum of these rates of commodity substitution. That is

$$(24) \qquad \sum_{j=1}^{s} \frac{\dfrac{\partial U^i}{\partial x_{j(n+1)}}}{\dfrac{\partial U^i}{\partial x^i_{jh'}}} = \frac{\dfrac{\partial F^j}{\partial x_{j(n+1)}}}{\dfrac{\partial F^j}{\partial x^i_{jh'}}}$$

Even so the solution will be Pare to optimal if these conditions can be satisfied.

One thing is clear from the preceding analysis and that is the fact that where collective goods are concerned it is no longer an individual consumer who alone decides what quantity of the good he will consume. Rather the entire community must somehow relate to each other their individual valuation of the collective good and then these individual valuations added and equated to the marginal cost of the collective good. Since we have not assumed uniform preference rankings for all consumers we cannot in turn assume "equal shares" of marginal cost.

In order to gain the fullest significance from these results it is necessary to again resort to an argument in dynamics. First and probably most important it is the opinion of all those who have studied collective goods in the equilibrium context that even though a Pareto optimal solution is theoretically possible there is no way that the pricing system will attain such a point. Samuelson [Ref. 34] said it first and every economist since has agreed that a decentralized pricing system will not optimally determine the levels of collective consumption.

The fundamental reason for the failure of the market system is generally felt to be that there is no mechanism available which will force

consumers to reveal their true preferences for collective goods. The consensus is that the "rational" consumer will understate his preference for a collective good and hope to gain the full benefit at the expense of others. Since all consumers are assumed to be rational, they all would behave in the same manner and thus if decisions were left to prices as determined by the market alone the only collective goods which would be produced would be those jointly produced with a private good.

This problem has been the subject of much recent study including various schemes for optimally providing public goods to specified localities and the theory of group decisions and actions. Note especially the work of Williams [Ref. 43], Connolly [Ref. 11] and Tiebout [Ref. 39]. Certainly the larger the group the more difficult and costly it becomes to obtain agreement upon a quantity of a collective good to be consumed by all. "Herein lies the explanation of the failure of market-like or exchange organization to function effectively in supplying public goods that jointly supply large groups" [Ref. 4]. A political or voting scheme is presently used to obtain consumer preferences for many of the non-privately supplied collective goods.

Now to recap briefly, two types of external effects have been applied to the perfect competition model. First external economies and diseconomies effected by producers upon consumers (and by consumers upon each other) were examined. The result was a divergence between social cost and private cost which could not be reconciled by the market mechanism alone. Next externalities caused by collective goods were investigated and it was concluded that because of failure to reveal true preferences for these goods, a market type exchange mechanism

could not determine the optimal quantity of this type good. Both of these conditions can be directly related to the environmental pollution problem. Most pollution is the result of actions which fall explicitly into the category of the externalities first studied. The clean up of a polluted area can be considered a classical example of a Samuelsonian collective good and therefore the preceding analysis has direct applicability.

V. INTERNALIZING THE EXTERNALITIES

For the final analysis of the study consider a world which includes private goods with external effects. However instead of representing an externality as an effect of the consumption or production of the precursor good consider it to be itself, a good. That is, in previous analyses an external diseconomy of production, smoke for instance, was accounted for by making each person's utility a function of the quantity of the precursor good consumed. In the present situation it is desirous to treat the external diseconomy, smoke, as a good which may be consumed by individuals. The reason for characterizing externalities in this manner is to attempt to "internalize" the externality. That is to obtain an equilibrium solution in which the Pareto optimal conditions infer some method of pricing (or taxing) the externality.

In order to follow somewhat the previous notation we will again consider a world of s consumers and k firms. Let goods x_1 through x_n be private goods and x_{n+1} through x_m be external economies and diseconomies. A necessary assumption for this analysis is that the externalities, be they economies or diseconomies, are producer initiated. Consider each of the "goods" x_{n+1} through x_m as outputs of firms and these commodities are consumed by individuals of the community. As such they will appear in the production and utility functions. Textbook formulation of the implicit production functions normally embraces only those inputs and outputs for which a price can be associated. For instance if air is used as a factor of production it usually is not included in the production function (unless it must be purified before use). Similarly even if noise or air pollutants are "joint products"

along with the salable products they are not "normally" included in the production functions.

There is no assumption made as to the collective characteristics of the external economies or diseconomies. An attempt is being made here to structure the problem so that there are no "collective" goods, services or externalities. That is, the producer produces only "my goods and your goods" and "mine" are always separate and distinct from "yours". Therefore only "private" type characterizations of commodities is present.

Thus each utility function will be of the form

$$(25) \quad U^i = U^i\,(x^i_{j1}, x^i_{j2}, \ldots, x^i_{jn}, x^i_{j(n+1)}, \ldots, x^i_{jm}); \qquad (j = 1,2,\ldots,k)$$

and production functions

$$(26) \quad F^j\,(x^i_{j1}, x^i_{j2}, \ldots, x^i_{jn}, x^i_{j(n+1)}, \ldots, x^i_{jm}) \leq 0; \qquad (i = 1,2,\ldots,s).$$

Utilizing the familiar maximization techniques of earlier sections, the equilibrium conditions become

$$(27) \quad W_i \frac{\partial U^i}{\partial x^i_{jh}} - \lambda_j \frac{\partial F^j}{\partial x^i_{jh}} \leq 0$$

and

$$(28) \quad x^i_{jh}\left[W_i \frac{\partial U^i}{\partial x^i_{jh}} - \lambda_j \frac{\partial F^j}{\partial x^i_{jh}}\right] = 0$$

for private goods $x_1, x_2, \ldots, x_n$.

$$(29) \quad W_i \frac{\partial U^i}{\partial x^i_{j(n+h)}} - \lambda_j \frac{\partial F^j}{\partial x^i_{j(n+h)}} \leq 0$$

and $$x^{i}_{j(n+h)} \left[\frac{\partial L}{\partial x^{i}_{j(n+h)}}\right] = 0$$

for external effects $x^{i}_{j(n+h)}$.

(29a) $$F^{j}(*) \leq 0$$

and $$\lambda_{j} \left(\frac{\partial L}{\partial \lambda_{j}}\right) = 0.$$

The conditions for "ordinary" private goods have been discussed previously. What is important in this model is the interpretation given to this characterization of external effects. From equation (29) comparing an external effect with the standard private good, h', gives a condition which appears to be identical with the private good. That is

(30) $$\frac{\dfrac{\partial U^{i}}{\partial x^{i}_{j(n+h)}}}{\dfrac{\partial U^{i}}{\partial x^{i}_{jh'}}} = \frac{\dfrac{\partial F^{j}}{\partial x^{i}_{j(n+h)}}}{\dfrac{\partial F^{j}}{\partial x^{i}_{jh'}}}$$

The right hand side of (30) is similar to the rate of product transformation for private and collective goods. Previous discussion has shown that RPT to be equal to the ratio of prices for the goods involved. The Pareto optimal conditions are also characterized by equality between the rate of commodity substitution between two private goods and their price ratio. Recall for collective goods, however, that it is the sum of all individual's RCS which is equal to the RPT for that good.

From (29) and (30) we have conditions which appear to be analogous to the pure private goods world; that is, the rate of product transformation between an external effect and some standard private good is

is equal to the consumers rate of commodity substitution. It now becomes necessary to interpret what is meant by RPT and RCS between some external effect and a private good or numeraire.

First from the firm's point of view the incidental nature of the external effect makes it very difficult to control the quantity of this "good" produced. Usually an external effect is unintentional in that it normally is a by product of some legitimate process and not a purposeful product [Ref. 26]. Also for the most part externalities are not marketable in the normal sense. Consumers will not pay a price for the privilege of "consuming" an externality. The reasons for this have been discussed earlier but to reiterate; first if an external economy is involved people realize that exclusion of the benefit from them is extremely costly and thus they will be supplied it whether they pay or not. Secondly if we are dealing with an external diseconomy a rational person would not pay a positive price for a disutility causing product. They may, however, be willing to pay for the removal or elimination of that product. It therefore would probably not be in a firm's interest to shift resources from a product for which a price, as commonly thought of, could be obtained to an external effect which would gain them no revenue. This might be disputed by some actual firms which have in recent months made announcements concerning funds which they have allocated for devices and methods of production which have no purpose other than the reduction of contaminating waste. It is highly unlikely that such actions have been influenced solely by the market pricing system however. More plausibly government pressure and "public opinion", both of which are external to the market, are the motivating forces for these acts. Even though the

consumer may indirectly compensate the firm through increased prices of the normal outputs, this does not really fit the model under present consideration.

Regarding the same situation from the viewpoint of the consumer note first that a utility function is a ranking of preference between different bundles of goods. Certainly a rational consumer would rather have a bundle of goods which included zero quantity of a good which provided dissatisfaction if consumed. Mathematically speaking a diseconomy can be characterized for the consumer by $\frac{\partial U^i}{\partial x^i} < 0$ where x^i is some quantity of a diseconomy producing good. Therefore the rate of commodity substitution between an external diseconomy and any private good which provides positive utility would be negative. Thus using the price ratio analogy this indicates that the consumer would be willing to "pay" a negative price for the privilege of "consuming" the diseconomy. Or turning it around the consumer will pay to get rid of a commodity which provides negative utility. So in theory there is some "price" which could be used to determine the optimal quantity of a diseconomy good to be supplied. The mechanism by which the "price" would be established is not clear and is surely not to be proposed in this paper.[10]

[10] Shapley and Shubik have used the game theory concept of the core of an n person cooperative game to show that a Pareto optimal competitive equilibrium exists under certain conditions involving externalities. In particular a pure private goods world in perfect competition with externalities in production was considered. The external effects were assumed to affect production processes and consumers directly through their utility functions. It was shown that if the externality was an economy (beneficial effects only) a Pareto optimal competitive equilibrium existed in all cases but if the externality was a diseconomy this was not always the case. They found wide diversity of core behavior when considering various examples of external diseconomies. There are no general conclusions for use of the core in examining external diseconomies although specific case-by-case application may be enlightening with regard to prospective Pareto optimum. Lloyd S. Shapley and Martin Shubik, "On the Core of an Economic System with Externalities," American Economic Review, Sept 1969.

Although the collectiveness of goods has been assumed away in this model it is this very fact (collectiveness) which appears to be the blocking effect in allowing this structure to reach its Pareto optimal conditions. As was seen in the private-collective goods model once a commodity begins to exhibit a collective characteristic it becomes impossible for one individual alone to determine the amount of that good which he will consume. Since most externalities are collective in nature it seems that even though the model requires "my goods and your goods" as separate entities, in actuality there will be some "our goods".

There are some situations, however, in which one individual consumes the entire amount of an external effect and all others consume none. Coase [Ref. 10] gives an example of such a situation involving a confectioner and a doctor who because of his close proximity to the confectioner's kitchen "consumed" all of the vibration and noise generated. Although this case was settled judicially it does seem as if it might have been handled through a price-like mechanism. The important point here is that if only two persons are involved the likelihood of a decentralized (no outside interference) solution is increased. When more than one individual has an interest on either side a collective solution is necessary. As previously determined a market system probably will not be efficient in allocating resources and distributing goods.

If in theory a world with private goods and "internalized" external effects has an equilibrium, can this point be attained in practice? At first glance most observers would answer this question in the negative; at least without some sort of centralized interference most would agree that such a bliss point will not be reached. The next few paragraphs will attempt to outline a few of the difficulties which prevent reaching the Pareto optimal point.

Returning to the environmental pollution problem, consider first the case of external diseconomies. A giant problem looms in the area of specifying the actual effect of the diseconomy upon those involved. As an example consider a factory which produces a single output, and in the process dumps its waste into a river which flows past the factory and on for several miles. Suppose the dumping costs the factory nothing. Suppose also that the waste causes the following effects: (a) ruins a previously well used recreational area, (b) contaminates the fish which thrive in the river and are regularly taken from some downstream area for human consumption, (c) forces a downstream firm to utilize additional funds to purify the water prior to use in its own production process. Now clearly we have here an example of externality in its most classic sense. The factors of locality and measurement now come into play.

To a non-fish eating individual with no desire for water recreation but who enjoys the commodity produced by the factory, the dumping of the waste into the river provides no external diseconomy. It might even provide this person with an external economy because he probably pays less for the commodity than if the factory had to divert some of its resources to process waste. Suppose another group of individuals can no longer use the river for boating and swimming. Although the services lost by those no longer able to use the river for recreation could be measured, say in hours of recreation per month, this does not necessarily indicate the "utils" they attach to the services lost. If they obtain similar recreational services but at a different location the cost of reaching the new area could be used as an indication of the value they place upon such services. Of course others may substitute other forms of recreation for which they will very likely experience less utility.

Consider now those persons who consumed the contaminated fish. The result to them could vary from none to a shortened life span and could include all sorts of maladies in between. Once again it is nearly impossible to provide a uniform and meaningful way to compare utility between persons. Then consider the factory which must purify its water. At least we can quantify the external diseconomy because the cost of purification can be directly related to the amount of waste dumped by the offending plant.

The point of this example is to demonstrate that one action, the dumping of waste, can affect many groups each in a different way. These groups may or may not consume the "real" output of the factory. If they do then possibly some type of equilibrium could be reached on an individual basis. But if they do not consume the product and considering the diverse measures of disutility it seems highly unlikely that a decentralized method could gain a Pareto optimal equilibrium point.

In practice incidents whereby consumers voluntarily enter into agreement with producers to settle upon a price for an external economy or diseconomy are few and far between. If a firm cannot exclude consumers from the benefit there is no way they can force payment. Additionally if firms contaminate a medium such as the air or water over which there are no property rights, then certainly they will not voluntarily contribute a reduction of the diseconomy at their own expense. The fact that the theoretical equilibrium discussed above is not actually attainable in real life has been the subject of much study in recent years. This study, although sometimes carried out in the context of equilibrium analysis, is actually an investigation of

the processes involved in moving the system from disequilibrium to equilibrium. The line between disequilibrium analysis and equilibrium analysis is quite fine in many areas. Thus many authors move back and forth from one to the other quite indiscriminately.

As has been noted earlier disequilibrium type discussions are necessary in order to determine the usefulness of the equilibrium analyses. The Pareto optimal conditions may not be attainable and this can only be seen through dynamic analysis. Previous note has been made of the so called divergence between private and social benefits caused by external effects. Although as we have seen there are conditions which if satisfied would still lead to a Pareto optimal situation, the general opinion throughout the literature seems to be that a decentralized pricing mechanism will not result in such an optimum. Several policy alternatives have been proposed and these will be briefly discussed in the following paragraphs.

The tax-subsidy policy has already been mentioned as one method of equating private and social costs. Until ten or fifteen years ago most economists subscribed to this scheme as the one which should be followed. Its basic premise is to levy a tax upon whoever creates an external diseconomy (or subsidize the producer of an external economy). Problems which arise when attempting such a policy include how much the tax should be, what the tax should be levied upon and who should obtain the revenue gained by the tax. Economists and others are not generally in agreement on any of these difficulties [Ref. 10, 31].

More recent work has indicated that regulating an externality with a government initiated tax scheme may be extremely difficult if not impossible [Ref. 7, 40]. The problem lies in the lack of information

about utility and cost functions from which equitable taxes can be determined. An alternative proposed by Davis and Whinston is based upon the motivation of two firms (or more) to merge, thus eliminating the externalities which they exert upon each other. Their model uses game theory to show the extreme difficulty involved in creating an effective tax scheme to compensate for certain types of externalities. Although severely restricted as to the interactions to which their analysis applies (producer-producer reciprocal) they are still able to point out the informational problems facing tax-subsidy policy makers.[11] Closely allied with this is the "bartering" approach which has been proposed by several authors. Essentially it is postulated that if the offending party and the party suffering the damage are willing and able to negotiate to their mutual advantage then there is no need for outside intervention in order to gain an optimal resource allocation. Bargaining is not restricted to any particular type of external interaction but there are some situations in which it would not be a reasonable alternative. Such cases might include a situation in which a large group is involved and the members cannot get together to to bargain or when their interests are diverse due to non-uniform

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[11] Otto A. Davis and Andrew Whinston, "Externalities, Welfare, and the Theory of Games," Journal of Political Economy, June 1962. A problem which is recognized by the authors concerns the possible alteration of the market structure due to mergers. That is in order to truly "internalize" an externality such widespread mergers might be necessary that the result is a monopolistic rather than a competitive market. It would then be necessary to determine whether the welfare gained through mergers outweighed the welfare lost through market alteration. See also References 15 and 17.

consumption of the externality.[12] (As in the river example cited previously). Of course there is no unanimity in any of the alternate proposals [Ref. 42]. The most logical approach toward the problem would be to consider each as having merit under certain circumstances. The legal aspects of external effects are becoming more important because of the increasing number of conflicts involving legal rights. The costs involved in mergers and bargaining also may be significant. As an example these costs might include the cost of identifying all members of the effected group, finding a unified course of action and the actual bargaining. The possibility also exists of finding a judicial solution in case governmental tax-subsidy, merger and bargaining all fail [Ref. 8].

In general we must conclude from the preceding that even if the market system will not automatically reach its equilibrium when externalities are present other methods do exist for attaining an optimal allocation of resources. What must be understood, however, is

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[12] Apparently the bargaining approach was first expounded by Coase [Ref. 10]. He was most concerned about the evident disregard by economists of the effects upon society of the tax-subsidy measurements. He advocated an approach which would consider the total effect of a given social arrangement and as a result the bargaining tactic appeared to merit some further study. Buchanan and Stubblebine [Ref. 7] expounded upon this theme and concluded the unilaterally imposed taxes would not be sufficient to attain Pareto optimality in the case of the externalities. Rather the total benefits must be weighed against the net costs to determine whether any intervention is required at all. Whinston and Davis proceeded to develop an iterative type model for bargaining which allowed individuals to gain knowledge of each other's preferences. Additionally they raised the question of the legal status quo. In other words the result of the bargaining process depends to a large degree upon the legal arrangements which initially govern the situation. The point is made again however that should the externality be imposed upon a large number of persons the tax-subsidy scheme may be more useful than bargaining. Otto A. Davis and Andrew B. Whinston, "Some Notes on Equating Private and Social Cost," The Southern Economic Journal, Oct 1965.

that at present there is no general theoretical approach which applies to all situations. Actually the final equilibrium might be found using a combination of the proposed alternatives. It is not the purpose here to make any attempt to rank the proposals or to even try to specify situations in which one method may be superior. Rather they have been used to point out the directions in which many economists have been concentrating their effort in recent years. Many of our most pressing problems (not only environmental pollution) appear in theory to fall under the cognizance of welfare economics. In the words of Wellisz [Ref. 42], "Perhaps... the welfare economists could do better than "practical men" if only they were able to apply their skills to the practical problems which cry for solutions".

VI. SUMMARY

There are several areas of extreme interest and relevance which have not been discussed but deserve mentioning as possible areas of further study. The first of these involves the optimal supply of public goods where public is used to mean collective goods supplied by governmental means. The nature of the necessary conditions for optimality in the world which included collective goods has led many economists to the conclusion that the market system alone will not attain a Pareto optimal equilibrium. The major reason which has been advanced deals with the high probability of false preference rankings by individuals. This is extremely difficult to verify empirically and is more a "feeling" on the part of those advocating this cause than actual fact. Certainly there is nothing to prevent a society to develop the customs and mores necessary to insure accurate representation of preferences but apparently this is thought to be an exception in our highly industrialized world.

If we accept that the pricing system alone will not optimally supply our public goods the question which naturally arises is "How do we determine the supply of public goods?" Obviously many public goods are being supplied now, have been in the past and will be in the future. What mechanism was used to decide upon the present mix of public goods and is this mix optimal? These questions and others directly related have provided impetus for several authors, notably Downs [Ref. 18], Black [Ref. 3], Olson [Ref. 29], and Buchanan [Ref. 6], to study the theory of group action. These writings are extremely interesting and provide some very thought provoking conclusions which are beyond the scope of this paper but which definitely provide an area for further

research. Clearly this has applicability to environmental pollution since the clean up of much of the contamination will very likely be accomplished collectively.

A problem which always seems to appear in any study of externalities is that of properly categorizing the external effect. An externality can be interpreted in many different ways and herein lies one of the greatest difficulties in reconciling the thoughts of various authors. The parameters of time and locality very often become important when characterizing the effect of some action. Sometimes they are considered and sometimes not.

Although this study has tended to look at the economy as a whole, this certainly does not imply that such methods must be restricted to a whole economy. Actually one of the new areas of investigation concerns the theory of resource allocation within a firm or organization. That is, the different divisions of an organization, be it government or private, normally compete for funds to carry out its specific tasks. Many times externalities will be exerted by one division upon another. Thus if a method to optimally allocate resources in a competitive market with external effects is known it might be able to be made applicable to government and industry [Ref. 32].

Finally since we opened this paper with a discussion of environmental pollution, we shall close with a brief review of the status. There are really no theoretical economic solutions to the pollution problem. Buchanan has, however, advanced an equilibrium model which attempts to explain in simple terms some reasons for pollution. He notes that in the past there has been a cult of "do gooders", those who see their public duty and do it. There are many examples,

especially in the less populated areas, where a certain group of well off individuals has provided goods and services which benefit the entire community with no apparent compensation. The problem of pollution, however, appears to be too large to be corrected by the voluntary action of a few. According to Buchanan we must "...change the structure of property rights which will make exclusion less costly or shift from voluntary individual and group behavior to some more inclusive collective and coercive action through the political process" [Ref. 5].

Ayers and Kneese [Ref. 1] have approached the problem from a completely different route. Theirs is a materials flow analysis which uses as its base the Walras-Cassel general equilibrium model. The information required at equilibrium is no different than that which was shown here in to be necessary for our perfect competition model. That is all preference and production functions must be known as well as all factor and process substitution. Thus it brings us no closer to a satisfactory answer as to whether a Pare to optimum can be reached or not.

The complexity of the problems concerning externalities and collective goods, both central to the control of pollution, have been enumerated. No particular solution is offered but surely one must realize that only positive action will solve our problems. Pollution is inevitable, its clean up is not. We must remember "To live is to pollute". [Ref. 12].

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Security Classification

DOCUMENT CONTROL DATA - R & D

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ORIGINATING ACTIVITY (Corporate author)	2a. REPORT SECURITY CLASSIFICATION
Naval Postgraduate School Monterey, California 93940	Unclassified
	2b. GROUP

REPORT TITLE

An Analysis of Collective Goods and External Effects Under Conditions of Complete Information and Pareto Optimality

DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Master's Thesis; September 1970

AUTHOR(S) *(First name, middle initial, last name)*

Thomas Alfred Meinicke

REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
September 1970	54	43

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3. ABSTRACT

The allocation of resources is a problem which is faced by all decision makers whether they be public servants or private entrepreneurs. Increasingly these decisions have required more information than can generally be obtained through the decentralized pricing system of perfect competition. Many of the so called social problems of today, specifically environmental pollution, are deeply rooted in economic concepts which seem to cause allocations which are not Pareto optimal if determined by the market alone. This paper is confined to the study of two of the more important of these concepts, collective goods and external effects (or externalities).

The basic economic structure utilized is that of perfect competition under a criteria of Pareto optimality. After characterizing the Pareto optimal conditions for a world of private goods with complete information, separate models were described which included externalities and collective goods. It is shown that if a Pareto optimal solution is to be gained certain conditions exist which must be satisfied. The difficulty in attaining such equilibrium conditions is then discussed with a dynamic connotation for pedagogical purposes only. The general conclusions are drawn that when collective goods and external economies and diseconomies are present the market system or mechanism alone will not yield a theoretical Pareto optimal point.

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N 0101-807-6811

Security Classification

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Collective goods						
Externalities